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SALT WATER BARRIERS IN THE SAN FRANCISCO BAY

by B. L. Nishkian

WATERWAYS DIVISION

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SALT WATER BARRIERS IN THE SAN FRANCISCO BAY

B.L.NISHKIAN
MEM. AM. SOC. C.E.

THE IDEA OF A SALT WATER BARRIER IN SAN FRANCISCO BAY IS CERTAINLY NOT A NEW ONE. SEVERAL EXTREMELY COMPREHENSIVE REPORTS HAVE BEEN PREPARED IN THE PAST. THE MOST COMPREHENSIVE ONE BEING THAT PREPARED BY WALKER YOUNG, ENGINEER WITH THE UNITED STATES BUREAU OF RECLAMATION, ENTITLED "SALT WATER BARRIER BELOW THE CONFLUENCE OF THE SACRAMENTO AND SAN JOAQUIN RIVERS". THIS REPORT WAS PRESENTED IN 1929 AFTER FIVE YEARS OF DETAILED INVESTIGATION. THE IDEA OF THE SALT WATER BARRIER WAS FIRST SUGGESTED NEARLY 75 YEARS AGO BY C. E. GRUNSKY IN 1880. MR. GRUNSKY WAS THE ASSISTANT STATE ENGINEER AT THAT TIME.

BECAUSE OF THE ENORMITY OF THIS PROJECT AND THE BRIEF TIME AVAILABLE THIS PAPER CAN ONLY BE A DISCUSSION OF ALL THE ADVANTAGES OF A SALT WATER BARRIER TO THE SAN FRANCISCO BAY AREA PLUS ARGUEMENTS AGAINST THE MAJOR OBJECTIONS TO A BARRIER SYSTEM.

THE IMPORTANCE OF SUCH A PROJECT IS WELL EVIDENCED BY THE NUMBER OF PUBLIC HEARINGS THAT HAVE BEEN HELD IN THE PAST FEW YEARS CONCERNING THE PROBLEM. IN THE OPINION OF MANY IT IS JUST A MATTER OF TIME UNTIL A BARRIER IS RECOGNIZED AS THE ULTIMATE SOLUTION TO THE MANIFOLD PROBLEMS OF THE BAY AREA.

THE SAN FRANCISCO BAY AREA HAS A NATURAL LOCATION THAT IS UNRIVALED. IT HAS AN IDEAL WORKING CLIMATE, ONE OF THE LARGEST NATURAL HARBORS IN THE WORLD AND, BECAUSE OF IT'S LOCATION, IS THE LOGICAL OUTLET FOR THE SACRAMENTO-SAN JOAQUIN VALLEY PRODUCE. THESE NATURAL ATTRIBUTES HAVE OBVIOUSLY BEEN THE REASON FOR THE AREAS RAPID POPULATION, INDUSTRIAL AND AGRICULTURAL GROWTH. HOWEVER, IF THIS RAPID GROWTH IS TO CONTINUE NATURE MUST BE AUGMENTED BY MAN MADE IMPROVEMENTS. THREE OF THE REQUIREMENTS FOR CONTINUED GROWTH ARE: ONE, AMPLE WATER SUPPLY: TWO, RAPID TRANSPORTATION AMONGST ALL COMMUNITIES; THREE, INDUSTRIAL LANDS THAT ARE CONVENIENT TO TRANSPORTATION AND ABUNDANT WATER. ALL OF THESE REQUIREMENTS CAN BE PROVIDED WITH A SALT WATER BARRIER. THE FIRST THOUGHT THAT COMES TO MIND IS "IS A BARRIER SYSTEM FEASIBLE?"

FROM A GENERAL INVESTIGATION OF THE PROBLEMS INVOLVED IT CAN DEFINITELY BE SAID THAT SUCH CONSTRUCTION IS FEASIBLE. THE BASIC CONSTRUCTION INVOLVES FILL, OVERFLOW STRUCTURES, SHIP LOCKS AND BRIDGES. THERE IS NOTHING NEW OR UNUSUAL REQUIRED IN SUCH CONSTRUCTION OTHER THAN MAGNITUDE.

THE ADVANTAGES OF A BARRIER SYSTEM ARE MANIFOLD. BY PROVIDING STORAGE FOR THE SACRAMENTO-SAN JOAQUIN RIVER AT ITS WESTERN TERMINUS IT BECOMES A MAJOR FACTOR IN WATER CONSERVATION IN THE BAY AREA. DURING A NORMAL YEAR 27,000,000 ACRE FEET FLOW INTO THE BAY AND OUT THE GOLDEN GATE FROM THE SACRAMENTO-SAN JOAQUIN RIVER. NONE OF THIS IS SAVED. HOWEVER, WITH A NORTHERN BARRIER IN PLACE A FRESH WATER LAKE OF 160,000 ACRES BECOMES AVAILABLE TO STORE SOME OF THIS FLOW. BECAUSE OF THE BARRIER THE 200,000 ACRE FEET OF WATER NOW DISCHARGED PER MONTH FROM SHASTA DAM FOR SALINITY CONTROL WILL BE SAVED. FURTHERMORE, IN AN EXTREMELY DRY YEAR OVER 1,000,000 ACRE FEET MAY BE OBTAINED FROM THE FRESH WATER LAKE BY PUMPING DOWN TO THE LOW TIDE LEVEL. WITH THIS AMOUNT OF STORAGE PLUS THE NORMAL SUPPLY THE BAY AREA WOULD BE ASSURED OF ADEQUATE WATER FOR DOMESTIC, AGRICULTURAL AND INDUSTRIAL USE FOR MANY YEARS TO COME.

THE TOP OF SUCH A BARRIER PROVIDES AN IDEAL CROSSING FOR VEHICULAR AND RAILROAD TRAFFIC. BECAUSE OF THE WIDTH OF THE TOP OF THE BARRIER FUTURE HIGHWAY LANES CAN BE PROVIDED AT A MINIMUM COST. THE ADDITIONAL EXPENSE REQUIRED TO PROVIDE A RAILROAD AND HIGHWAY CROSSING ON TOP OF THE BARRIER WOULD BE A SMALL PART OF THE $50,000,000. NOW BEING CONTEMPLATED BY THE STATE FOR A HIGHWAY CROSSING ONLY.

THE SURROUNDING SALT MARSHES CAN BE RECLAIMED AND WOULD PROVIDE GOOD INDUSTRIAL SITES WITH WHARF POSSIBILITIES ON A BODY OF FRESH WATER WITH A NEAR CONSTANT LEVEL. THE FRESH WATER BEING PRESENT IN SUFFICIENT QUANTITY TO PROVIDE WATER FOR THE MOST DEMANDING INDUSTRIAL PROCESSES.

AT THE PRESENT TIME THERE ARE MANY WHARVES AND WATER FRONT STRUCTURES BUILT IN THE AREA ABOVE THE PROPOSED SITE OF THE SALT WATER BARRIER. WITH THE BUILDING OF A BARRIER AND THE RESULTANT FRESH WATER ONE OF THE COSTLY MAINTAINANCE PROBLEMS WOULD BE PERMANENTLY SOLVED, THAT IS THE QUESTION OF TORREDO. IN THE PERIOD FROM 1913 TO

TO 1921, WHICH WAS AN EXTREMELY DRY ONE, THE DAMAGE DONE TO WHARVES IN THE UPPER BAY, DUE TO THE ENCHROACHMENT OF SALT WATER AND ITS ACCOMPANYING PROBLEMS, AMOUNTED TO APPROXIMATELY 25 MILLION DOLLARS (1921 COSTS). THE SALINITY CONTROL PROVIDED HAS BEEN ALREADY INDICATED IN THE PREVIOUS ADVANTAGES LISTED. SALINITY CONTROL MUST BE MAINTAINED AT ALL TIMES WHETHER BY BARRIER OR BY RELEASE OF MOUNTAIN STORAGE AS IS DONE AT PRESENT. THE FOLLOWING QUOTATION FROM THE WALKER YOUNG REPORT, PAGE 33, BEST DESCRIBES THE SITUATION. IN THIS QUOTATION CERTAIN WORDS AND PHRASES HAVE BEEN UNDERLINED BY THE WRITER FOR EMPHASIS.

> "SALINITY IN THE DELTA CAN BE CONTROLLED THROUGH CONSTRUCTION OF STORAGE RESERVOIRS IN THE MOUNTAINS FROM WHICH WATER COULD BE RELEASED DURING THE SEASON OF LOW RIVER DISCHARGE IN THE AMOUNT NECESSARY TO ACT AS A NATURAL BARRIER AGAINST INVASIONS OF SALT WATER. MOUNTAIN STORAGE WOULD BE A TEMPORARY EXPEDIENT FOR THE REASON THAT, UNTIMATELY, THERE WILL BE USE FOR ALL OF THE AVAILABLE FLOW FROM THE RIVERS, AND THE DISCHARGE INTO THE SUISAN BAY AND THENCE TO THE OCEAN, OF WATER SUFFICIENT TO ACT AS A NATURAL BARRIER AGAINST SALT WOULD BE AN ECONOMIC WASTE. HOWEVER, STORAGE CREATED IN MOUNTAIN RESERVOIRS CONSTRUCTED MAINLY FOR OTHER PURPOSES MIGHT ADVANTAGEOUSLY BE USED FOR SOME TIME TO CONTROL THE SALINITY IN THE UPPER BAYS AND DELTA CHANNELS DURING DEVELOPMENT OF THE REQUIREMNET FOR FULL USE OF THE RESERVOIRS FOR THE PURPOSE FOR WHICH THEY WERE PRIMARILY CONSTRUCTED. THUS DEFERRING THE LARGE INVESTMENT IN THE SALT WATER BARRIER".

REGARDLESS OF THE NUMEROUS ADVANTAGES TO A BARRIER THERE ARE MANY INDIVIDUALS AND GROUPS THAT OBJECT TO SUCH A PROJECT. THERE ARE FOUR MAJOR OBJECTIONS TO THE BARRIER. THE FOREMOST IS -- "THE WATER LOSSES DUE TO SUCH A SYSTEM WILL BE GREATER THAN THE SUPPLY" IN OTHER WORDS, A BARRIER WOULD WASTE FRESH WATER RATHER THAN CONSERVE IT. IT IS DIFFICULT TO VISUALIZE JUST HOW ANY BARRIER OR DAM WILL WASTE WATER. PARTICULARLY WHEN WITHOUT THE BARRIER ONE HUNDRED PERCENT OF THIS FLOW ENTERS THE PACIFIC OCEAN. TO BE SURE, ONCE THE RESERVOIR IS FULL THE SURPLUS MUST GO OVER THE BARRIER JUST THE SAME AS WATER GOES OVER SHASTA DAM ONCE IT IS FULL. HOWEVER, LET US CONSIDER

THE SOURCES OF LOSS IN SUCH A SYSTEM. THEY ARE:

1. EVAPORATION FROM THE LAKE SURFACE
2. OPERATION OF THE LOCKS
3. LEAKAGE AROUND THE GATES OF THE LOCK
4. OPERATION OF A FISH LADDER

THESE LOSSES REPRESENT A TOTAL OF ABOUT 1,200,000 ACRE FEET PER YEAR. THESE FIGURES ARE TAKEN FROM THE WALKER YOUNG REPORT AND ARE ON THE CONSERVATIVE SIDE DUE TO THE EXTRAVAGENT USE OF FRESH WATER IN THE LOCKS TO KEEP THE SALT WATER FROM INFILTRATING THE FRESH WATER LAKES. THE LOSSES THROUGH THE LOCKS COULD BE MINIMIZED BY THE USE OF SOME TYPE OF SALT CLEARING LOCKS OR BY THE USE OF LARGE SUMPS ON THE FRESH WATER SIDE OF THE LOCKS FROM WHICH SALT WATER COULD BE PUMPED AS IT ENTERED. TO OFFSET THESE LOSSES THERE IS THE SAVINGS THAT WOULD RESULT FROM NOT HAVING TO WASTE 200,000 ACRE FEET PER MONTH FROM SHASTA DAM IN ORDER TO CONTROL SALINITY IN THE DELTA REGION, THE AMOUNT OF RAINFALL ON THE FRESH WATER LAKE AND WATER FROM THE SAN FRANCISCO BAY AREA WATER SHED ITSELF. THESE THREE ITEMS TOTAL OVER 3 1/2 MILLION ACRE FEET YEARLY. REFERENCE TO TABLE NO. 1 WHICH INDICATES WATER SUPPLY AND USE IN A NORMAL YEAR AND TO TABLE NO. 2 WHICH GIVES THE SAME INFORMATION FOR 1931 THE DRIEST YEAR ON RECORD WILL SHOW THE NET MONTHLY EXCESS OF WATER. THESE TABLES INDICATE THAT EVEN DURING THE DRIEST YEAR ON RECORD THERE WOULD BE A SURPLUS OF WATER FOR INDUSTRIAL USE OR TO GO OVER THE SPILLWAY. IN ADDITION TO THIS SURPLUS THERE WOULD BE THE LARGE FRESH WATER STORAGE MENTIONED EARLIER. THIS STORAGE EQUALS 160,000 ACRE FEET PER FOOT OF DRAW DOWN. THIS REPRESENTS A 640 DAY SUPPLY FOR THE CITY OF SAN FRANCISCO FOR EACH FOOT OF DRAW DOWN.

A FOURTH SOURCE OF SUPPLY FOR COUNTERACTING THESE LOSSES, AND WHICH IS NOT CONSIDERED AT ALL IN THE ABOVE MENTIONED TABLES, IS RETURN WATER. IT HAS NOT BEEN CONSIDERED BECAUSE IT IS AN UNKNOWN QUANTITY. HOWEVER, FROM AVAILABLE INFORMATION, AN ULTRA-CONSERVATIVE ESTIMATE WOULD BE AT LEAST 300,000 ACRE FEET PER YEAR.

IT HAS BEEN CLAIMED THAT IT WOULD BE IMPOSSIBLE TO KEEP THE WATER FROM BECOMING BRACKISH DUE TO SEEPAGE OF SALT WATER THROUGH THE FILL. HOWEVER, DURING A NORMAL YEAR THERE WOULD BE A GREAT ENOUGH SURPLUS OF FRESH WATER TO FLUSH OUT THE LAKE ANNUALLY.

TABLE I

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SUPPLY & LOSS OF WATER TO LAKE
(IN 1,000 ACRE FEET)
1927 (NORMAL YEAR)

MONTH	(1) STREAM FLOW OF SACRAMENTO AND SAN JOAQUIN RIVERS INTO SUISAN BAY	(2) NAPA RIVER & LOCAL STREAMS	(3) RAINFALL ON LAKE	(4) LOSS DUE TO EVAPORATION	(5) LOSS FROM SHIP LOCKS & FISH LADDERS	(6) LEAKAGE	(7) EXCESS WATERS
JAN.	2,904	120	45	15	45	10	2,999
FEB.	7,670	100	78	18	41	10	7,779
MAR.	4,034	80	25	27	45	10	4,057
APR.	4,147	80	22	39	44	10	4,156
MAY	2,948	40	1	57	45	10	2,877
JUNE	1,886	40	4	72	44	10	1,804
JULY	300	20	0	75	45	10	190
AUG.	213	20	0	70	45	10	108
SEPT.	296	20	0	61	44	10	201
OCT.	523	40	22	48	45	10	482
NOV.	1,243	80	36	30	44	10	1,275
DEC.	1,405	160	45	12	45	10	1,543
TOTAL	27,569	800	278	524	532	120	27,471

SUPPLY & LOSS OF WATER TO LAKE
(IN 1,000 ACRE FEET)
1931 (DRIEST YEAR)

MONTH	(1) STREAM FLOW OF SACRAMENTO AND SAN JOAQUIN RIVERS INTO SUISAN BAY	(2) NAPA RIVER AND LOCAL STREAMS	(3) RAINFALL ON LAKE	(4) LOSS DUE TO EVAPORATION	(5) LOSS FROM SHIP LOCKS AND FISH LADDERS	(6) LEAKAGE	(7) EXCESS WATERS FLOWING INTO OCEAN
JAN.	808	30	63	15	45	10	831
FEB.	674	25	13	18	41	10	643
MAR.	823	20	19	27	45	10	780
APR.	410	20	3	39	44	10	340
MAY	203	10	13	57	45	10	114
JUNE	196	10	3	72	44	10	83
JULY	203	5	0	75	45	10	73
AUG.	203	5	0	70	45	10	83
SEPT.	196	5	0	61	44	10	76
OCT.	243	10	8	48	45	10	158
NOV.	425	20	38	30	44	10	399
DEC.	1,480	40	106	12	45	10	1,559
TOTAL	5,864	200	266	524	532	120	5,139

THE SECOND MAJOR OBJECTION TO THE BARRIER PLAN IS THE DETRIMENTAL EFFECT ON THE DELTA AREA. MUCH HAS BEEN MADE OF THE EFFECT ON THE DELTA AREA BY THE BARRIER PLAN AND ADMITTEDLY THERE WILL BE CAUSE FOR REHABILITATION OF SOME OF THE VARIOUS LEVIES. HOWEVER, THE COST OF REPAIRING THESE LEVIES IS SMALL IN COMPARISON WITH THE VAST VALUES RECEIVED FROM THE OVER-ALL PLAN. THE ELEVATION OF THE WATER SURFACE OF THE LAKE WOULD BE SOMEWHERE BETWEEN 4 AND 5 FEET ABOVE MEAN SEA LEVEL WHEREAS, THE LEVIES WHICH ARE NOT OF UNIFORM HEIGHT VARY GENERALLY FROM ELEVATIONS OF 6.5 TO 9 FEET ABOVE MEAN SEA LEVEL. THE LEVIES THAT LIMIT THE HEIGHT OF WATER AT PRESENT ARE FOR THE GREATER PART CONSTRUCTED OF PEAT.

INVESTIGATIONS AND THE OPINIONS OF ENGINEERS, REPRESENTING THE DELTA LANDOWNERS, INDICATE THAT IN THE PRESENT LEVIES WATER ELEVATION OF 3.5 FEET IS SOMEWHERE NEAR THE PRACTICAL LIMIT. THUS THE CONTROLLING LEVIES WOULD NEED TO BE INCREASED ABOUT 1 FOOT. IN ORDER TO INCREASE THE LEVEL APPROXIMATELY 1 FOOT INVOLVES 450-500 MILES OF PEAT LEVIES AND SOME 200 MILES OF SILT LEVIES. ADDITIONS TO THE SILT LEVIES WOULD NOT BE EXTENSIVE BUT THE BASE OF THE PEAT LEVIES WOULD HAVE TO BE WIDENED CONSIDERABLY TO PREVENT EXCESSIVE SEEPAGE AND TO INSURE STABILITY.

THE NEXT MAJOR OBJECTION TO A BARRIER IS THE EFFECT ON THE GOLDEN GATE BAR AND THE EFFECT UPON PRESENT SILT MOVEMENTS IN THE HARBOR AREA. THIS IS A QUESTION ABOUT WHICH THERE HAS BEEN MUCH DISCUSSION. HOWEVER, NO DEFINITE STATEMENT CAN BE MADE REGARDING THE EFFECT ON THE GOLDEN GATE BAR WITHOUT CONSIDERABLE STUDY. AT THE PRESENT TIME CONSTANT DREDGING OF THE SAN FRANCISCO BAR IS REQUIRED AND PROBABLY WILL CONTINUE TO BE REQUIRED. EVEN IF DOUBLE THE AMOUNT OF DREDGING BECAME NECESSARY DUE TO A BARRIER THE ADDITIONAL COST WOULD AGAIN BE SMALL COMPARED TO THE OVERALL BENEFIT OF A BARRIER. THERE IS ONE INTERESTING FACT WHICH SHOULD BE MENTIONED IN CONNECTION WITH THE DREDGING OF THE BAR AND THAT IS THAT THE SIZE OF THE BAR HAS BEEN DECREASING FOR DECADES IN WIDTH WITHOUT ANY MEASUREABLE DIFFERENCE IN HEIGHT WHILE THE TIDAL PRISM HAS DECREASED ABOUT 7 1/2 % IN THE LAST 75 YEARS DUE TO MARGINAL FILLING OPERATIONS, THUS INDICATING THAT A DECREASE IN THE TIDAL PRISM DOES NOT NECESSARILY MEAN THAT THE SIZE OF THE GOLDEN GATE BAR WILL INCREASE. HOWEVER, THE ULTIMATE ANSWER TO THE QUESTION OF THE EFFECT UPON THE TIDAL BAR CAN ONLY BE OBTAINED BY A THOROUGH MODEL STUDY OF THE WHOLE BAR AREA.

ANOTHER OBJECTION HAS BEEN THE INCONVENIENCE TO SHIPPING IN THE NORTHERN BAY. ADMITTEDLY THE NECESSITY OF GOING THROUGH LOCKS WOULD BE AN INCONVENIENCE TO SHIPPING. HOWEVER, THIS INCONVENIENCE IS AT LEAST PARTLY OFFSET BY THE NEARLY CONSTANT LEVEL OF THE LAKE. THIS CONSTANT LEVEL GREATLY FACILITATES CARGO DISCHARGE. THE CONSTANT LEVEL ALSO ELIMINATES TIDAL CURRENTS WHICH IS A TIME SAVER AND THE GREATER MINIMUM DEPTH OF WATER PROVIDES GREATER SAFETY AND MANEUVERABILITY. ANOTHER ITEM TO BE CONSIDERED IS THE CLEANING OF SHIPS BOTTOMS OF MARINE GROWTH, DEPENDING UPON THE TIME SPENT IN THE FRESH WATER.

ALL OF THE FIGURES GIVEN ABOVE ARE BASED ON A BARRIER BEING LOCATED WITH ITS WESTERN END AT SAN QUENTIN POINT AND ITS EASTERN END AT CASTRO POINT (SEE FIG. 1) HOWEVER, THE EXACT LOCATION CALLS FOR A MODEL STUDY AS INDICATED ABOVE. ALONG WITH THE MODEL STUDY OF THE EFFECT ON THE TIDAL PRISM AN INVESTIGATION SHOULD BE MADE CONCERNING THE EXACT LAKE LEVEL; THE LOCATION AND NUMBER OF LOCKS; THE QUESTION OF A HIGH LEVEL CROSSING AS COMPARED TO TUBES UNDER THE LOCKS OR A LIFT BRIDGE WITH 60-70 FOOT CLEARANCE WHEN IN PLACE.

WHEN THE ADVANTAGES OF A NORTHERN BARRIER ARE MADE APPARENT THE QUESTION OF A SOUTHERN BARRIER COMES TO MIND. ALL OF THE SAME ADVANTAGES PREVAIL. IN PARTICULAR IT MEETS THE URGENT NEED FOR AN ADDITIONAL VEHICULAR CROSSING FROM SAN FRANCISCO TO OAKLAND. SUCH A SOUTHERN CROSSING COULD BE MADE WIDE ENOUGH TO PROVIDE INDUSTRIAL SITES ON THE EDGES WITH THE RAIL AND HIGHWAY FACILITIES IN THE CENTER. IN THIS LOCATION IT WOULD BE MORE ADVANTAGEOUS TO PLACE UNDERWATER TUBES FOR ALL RAIL AND HIGHWAY FACILITIES. IF SUCH A BARRIER WERE MADE 2000 FEET WIDE IT WOULD PROVIDE APPROXIMATELY 650 ACRES OF INDUSTRIAL PROPERTY THAT WOULD HAVE RAIL, HIGHWAY AND DEEP WATER FRONTAGE. OBVIOUSLY A HIGHLY DESIRABLE COMBINATION (SEE FIG. 2).

THE BULK OF THE WATER REQUIRED TO FRESHEN A SOUTHERN LAKE WOULD HAVE TO BE PUMPED FROM THE NORTHERN END OF THE BAY THROUGH A SYSTEM OF CANALS. THIS SEEMS LIKE A SMALL PROJECT WHEN ONE REALIZES THAT THE WATER PROBLEM IS SO ACUTE IN SOUTHERN CALIFORNIA THAT SOME GROUPS ARE SERIOUSLY CONSIDERING AN ATTEMPT TO BRING WATER TO SOUTHERN CALIFORNIA FROM OREGON. THE EXACT LOCATION OF A SOUTHERN BARRIER IS AGAIN SUBJECT TO A MODEL STUDY. FOR THE PURPOSES OF THIS REPORT IT HAS BEEN LOCATED WITH ITS WESTERN TERMINUS NEAR TOWNSEND STREET AND ITS EASTERN TERMINUS AT THE SOUTHWEST END OF OAKLAND (SEE FIG. 2)

IT WOULD SEEM THAT ALL OF THE OPPONENTS OF A SYSTEM OF BARRIERS FORGET THE MANIFOLD ADVANTAGES OF SUCH A SYSTEM AND GENERALLY CONCENTRATE ON THE ECONOMIC VALUE OF A SINGLE FEATURE. THE ENTIRE COST IS WRITTEN OFF AGAINST WATER CONSERVATION OR AGAINST VEHICULAR CROSSINGS. THE COMBINED VALUE OF THESE TWO PLUS ALL OF THE OTHER ABOVE MENTIONED BENEFITS MUST BE EQUATED WITH THE COST TO ARRIVE AT THE CORRECT ANSWER AS TO WHETHER A BARRIER SYSTEM IS ECONOMICALLY JUSTIFIED OR NOT.

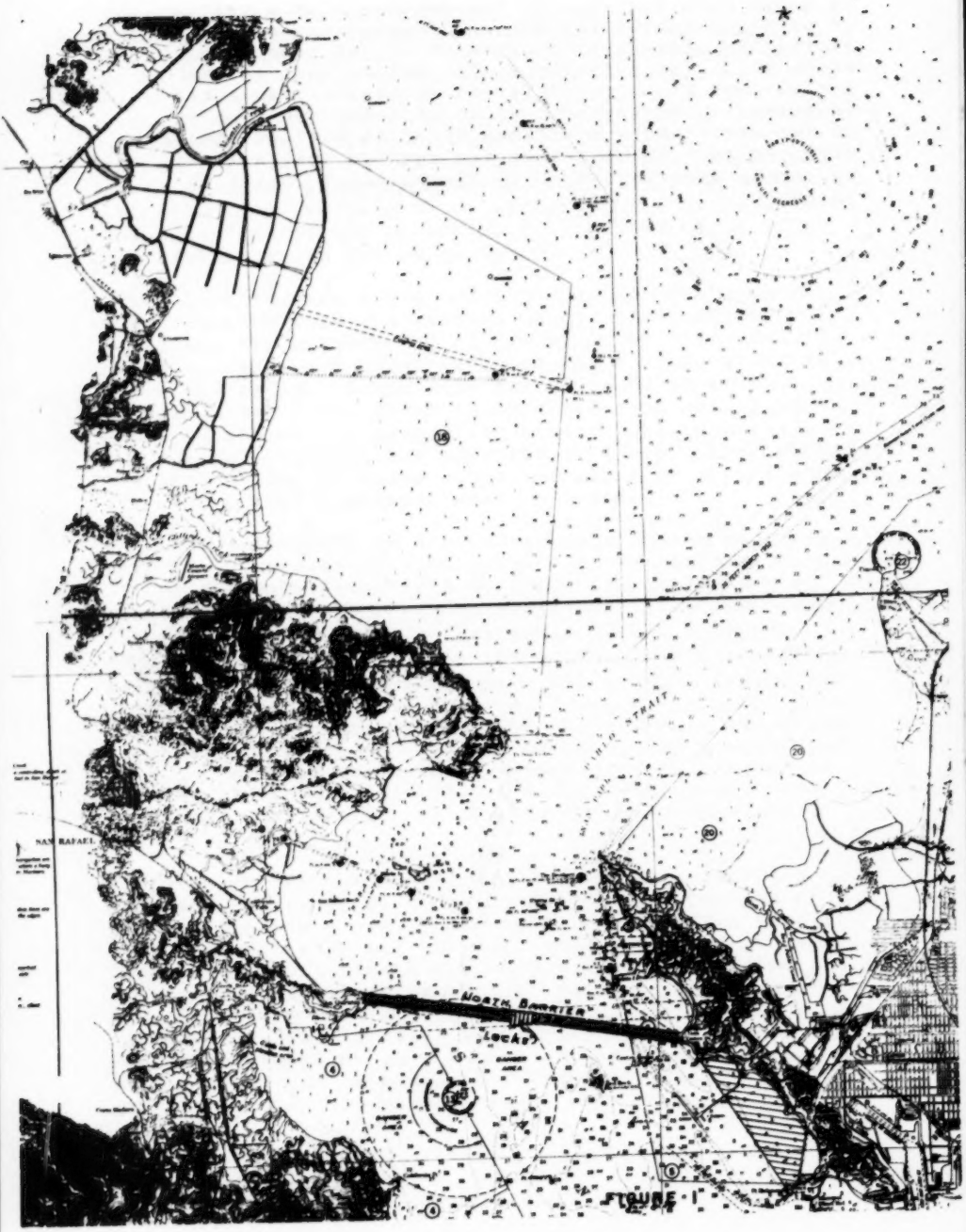

FIGURE 1

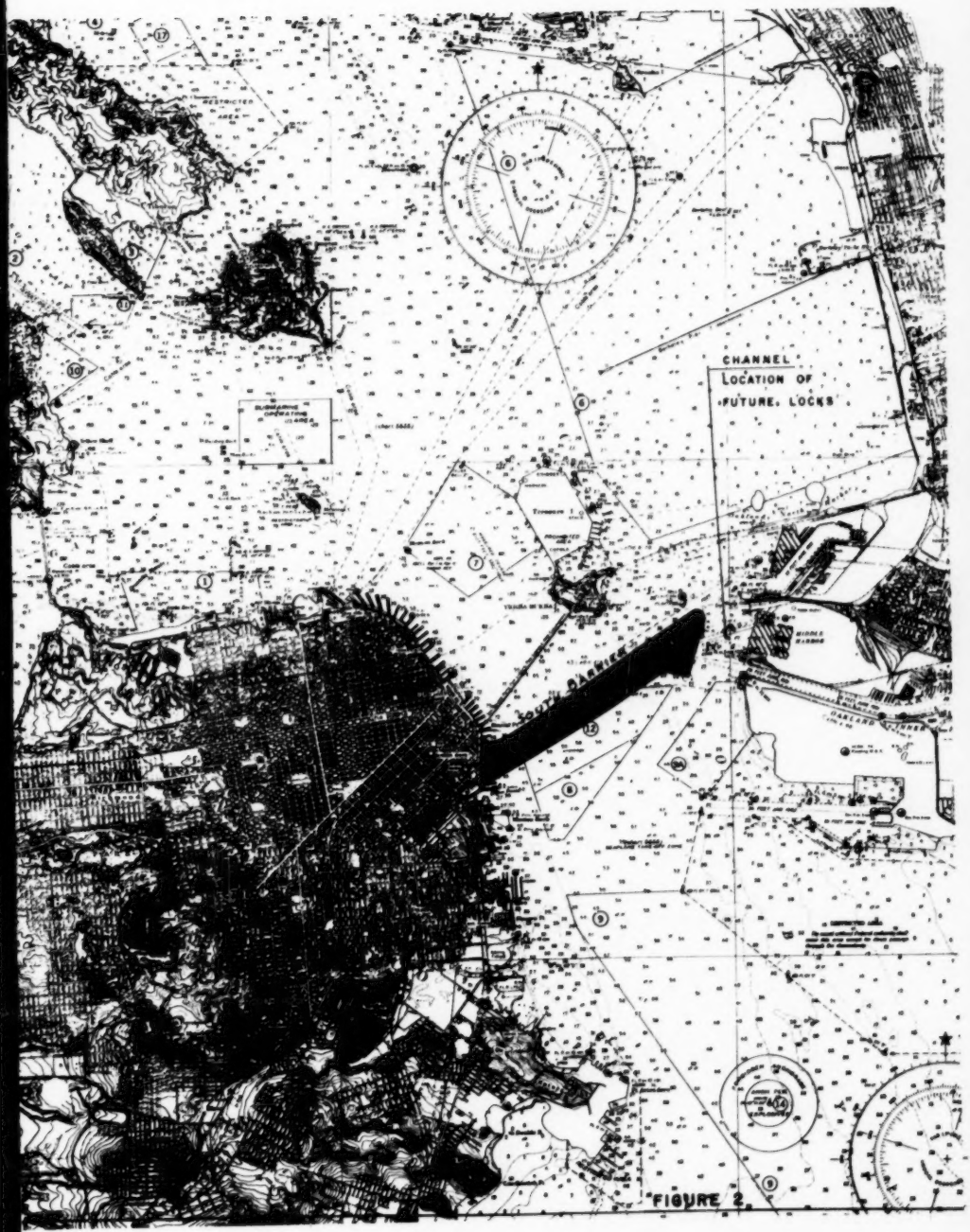

FIGURE 2

PROCEEDINGS OF THE SOCIETY

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